1 INTRODUCTION

This report presents the final results of a three-year cycle of sampling conducted by the Maryland Biological Stream Survey (MBSS or the Survey) to assess the "state of the streams" throughout the state. Previous reports documented interim results from the 1995 (Roth et al. 1997) and 1996 (Roth et al. 1997) sample years. This introductory chapter recounts the origin of the Survey, describes its components, and provides a roadmap to the report.

1.1 ORIGIN OF THE MBSS

More than 10 years ago, the Maryland Department of Natural Resources (DNR) recognized that atmospheric deposition was one of the most important environmental problems resulting from the generation of electric power. The link between acidification of surface waters and acidic deposition resulting from pollutant emissions was well established and many studies pointed to adverse biological effects of low pH and acid neutralizing capacity (ANC). Decreased growth and reproductive potential of adult fish and increased mortality rates of eggs and larvae were of greatest concern (Klauda 1989, Baker et al. 1990a, Morgan et al. 1991). To determine the extent of acidification of Maryland streams resulting from acidic deposition, DNR conducted the Maryland Synoptic Stream Chemistry Survey (MSSCS) in 1987. The MSSCS estimated the number and extent of streams at that time affected by or sensitive to acidification statewide. They concluded that the greatest concentration of fish resources at risk may be in streams throughout the Appalachian Plateau and Coastal Plain physiographic provinces (Knapp et al. 1988).

While the MSSCS demonstrated the potential for adverse effects on biota from acidification, little direct information was available on the biological responses of Maryland streams to water chemistry conditions. Data that were available could not be used (because of methodological differences and/or spatial coverage limitations) to compare conditions across regions or watersheds (Tornatore et al. 1992). Neither was it possible to assess the interactions between acidic deposition and other anthropogenic and natural influences (CBRM 1989). For these reasons, in 1993, DNR created the MBSS to provide comprehensive information on the status of biological resources in Maryland streams and how they are affected by acidic deposition and other cumulative effects of anthropogenic stresses.

1.2 DESCRIPTION OF THE MBSS

The MBSS is intended to help environmental decision-makers protect and restore the natural resources of Maryland. The primary objectives of the MBSS are to

- assess the current status of biological resources in Maryland's non-tidal streams;
- quantify the extent to which acidic deposition has affected or may be affecting biological resources in the state;
- examine which other water chemistry, physical habitat, and land use factors are important in explaining the current status of biological resources in streams;
- compile the first statewide inventory of stream biota;
- establish a benchmark for long-term monitoring of trends in these biological resources; and
- target future local-scale assessments and mitigation measures needed to restore degraded biological resources.

To meet these and other objectives of the MBSS, a list of 64 questions that the Survey will try to answer was developed (see Appendix A). These questions fall into three categories: (1) characterizing biological resources, physical habitat, and water quality (such as the number of fish in a watershed or the number of stream miles with pH < 5), (2) assessing the condition of these resources (as deviation from minimally impaired expectations), and (3) identifying likely sources of degradation (by delineating relationships between biological conditions and anthropogenic stresses).

Answering these questions has required a progression of steps in the implementation of the Survey, including (1) devising a sampling design to monitor non-tidal streams throughout the state and allow area-wide estimates of the extent of the biological resources, (2) implementing sampling protocols and quality assurance/quality control procedures to assure data quality and precision, (3) developing indicators of biological condition so that degradation can be evaluated as a deviation from reference expectations, and (4) using a variety of analytical methods to evaluate the relative contributions of different anthropogenic stresses.

In creating the Survey, DNR implemented a probability-based sampling design as a cost-effective way to characterize statewide stream resources. By randomly selecting sites, the Survey can make quantitative inferences about the characteristics of all 9,258 miles of first-to-third-order, non-tidal streams in Maryland (based on stream length on a 1:250,000-scale base map). The U.S. Environmental Protection Agency (EPA) is encouraging the use of random sampling designs to assess status and trends in surface water quality (EPA 1993). The initial MBSS design began with the MSSCS sample frame and was modified during the 1993 pilot and 1994 demonstration phases to provide answers to the questions of greatest interest (Vølstad et al. 1995, 1996). The final design allows robust estimates at the level of stream size (Strahler orders 1, 2, and 3), large watershed (17 river basins), and the entire state. Estimates by other categories, such as counties or smaller watersheds (138 in Maryland), are possible depending on the number of sample points in each unit.

DNR recognized that the utility of these estimates depended on accurately measuring appropriate attributes of streams. The Survey focuses on biology for two reasons: (1) organisms themselves have direct societal value and (2) biological communities integrate stresses over time and are a valuable and cost-effective means of assessing ecological integrity (i.e., the capacity of a resource to sustain its inherent potential). Inevitably, overall environmental degradation is tied to a failure of the system to support biological processes at a desired level (Karr 1993). It is equally important to recognize that the natural variability in biota requires that several components of the biological system be monitored.

Fish are an important component of stream integrity and one that also contributes to substantial recreational values. For these reasons, fish communities are the primary focus of the Survey. The Survey collects quantitative data for the calculation of population estimates for individual fish species (both game and nongame). These data can also be used to evaluate fish community composition, individual fish health, and the geographic distribution of commercially important, rare, or non-indigenous fish species. Benthic (bottom-dwelling) macroinvertebrates are another essential component of streams and they constitute the second principal focus of the Survey. The Survey uses rapid bioassessment procedures for collecting benthic macroinvertebrates; these semi-quantitative methods permit comparisons of relative abundance and community composition, and have proven to be an effective way of assessing biological integrity in streams (Hilsenhoff 1987, Lenat 1988, Plafkin et al. 1989, Kerans and Karr 1994, Resh 1995). The Survey also records the presence of amphibians and reptiles (herpetofauna), freshwater mussels, and aquatic plants (both submerged aquatic vegetation (SAV) and emergent macrophytes). The Survey has established rigorous protocols (Kazyak 1996) for each of these sampling components, as well as training and auditing procedures to assure that data quality objectives are met.

Although the MBSS sampling design and protocols provide exceptional information for characterizing the stream resources in Maryland, designation of degraded areas and identification of likely stresses requires additional activities. Assessing the condition of biological resources (whether they are degraded or undegraded) requires the development of ecological indicators that permit the comparison of sampled segment results to minimally impacted reference conditions (i.e., the biological community expected in watersheds with little or no human-induced impacts). The Survey has used its growing database of information collected with consistent methods and broad coverage across the state to develop and test indicators of individual biological components (i.e., fish and benthic macroinvertebrates) and physical habitat quality. Each of these indicators consists of multiple metrics using the general approach developed for the Index of Biotic Integrity (IBI) (Karr et al. 1986, Karr 1991) and the Chesapeake Bay Benthic Restoration Goals (Ranasinghe et al. 1994). The fish and benthic IBIs (which combine attributes of both the number and the type of species found) are widely accepted indicators that have been adapted for use in a variety of geographic locations (Miller et al. 1988, Cairns and Pratt 1993, Simon 1999). The Survey is investigating the possibility of developing additional indicators (e.g., amphibians in small streams with few or no fish) and combining components into a composite indicator of biological integrity.

In addition to developing reference-based indicators, the Survey is applying a variety of analytical methods to the question of which stresses are most closely associated with degraded streams. This involves correlational and multivariate analyses of water chemistry, physical habitat, land use, and biological information (e.g., presence of non-native species). The biological information also provides an unusual opportunity for evaluating the status of biodiversity across the state; the distribution and abundance of species previously designated as rare only by anecdotal evidence can be determined and unique combinations of species at the ecosystem and landscape levels can be identified. Land use and other landscape-scale metrics will play an important role in identifying the relative contributions of different stresses to the cumulative impact on stream resources. This report makes significant progress in quantifying known stresses and investigating their impacts on biological resources. Ultimately, the Survey seeks to provide an integrated assessment of the problems facing Maryland streams that will facilitate interdisciplinary solutions.

1.3 THE 1995-1997 STATEWIDE MBSS REPORT

This statewide report is the culmination of the progress made by the Survey over the last five years. In 1993, the Survey conducted a Pilot Study in four watersheds, two each in the Appalachian Plateau and Coastal Plain physiographic provinces (Vølstad et al. 1995). The Pilot Study evaluated the feasibility of conducting the random sampling program and developed estimates of the time requirements and costs to implement a full-scale Survey. In 1994, a Demonstration Project was conducted to refine logistics and protocols at the larger spatial scale needed for implementation and to determine which questions the program could successfully address with available resources (Vølstad et al. 1996). The Survey used information gained from the Demonstration Project to refine the study design to obtain the precision in the results needed to answer the questions of greatest interest, i.e., those at the scale of stream order or large watershed (river basin). The final sampling design was implemented over three years—1995, 1996, and 1997. The 1995 and 1996 MBSS reports presented the results of sampling in those years (i.e., for the basins sampled in those years), while this statewide report assesses all 17 basins and provides statewide estimates encompassing the full array of Maryland's ecological conditions.

The 1995-1997 MBSS incorporates and builds upon advances made over the 5-year life of the Survey. Estimates of fish abundance incorporate the results of double-pass depletion, a gear efficiency method developed for the 1995 MBSS that corrects for the relative capture efficiency of electrofishing different species (Heimbuch et al. 1997). The Index of Biotic Integrity (IBI) for fish, developed initially using MBSS data collected in 1994 and 1995 (Roth et al. 1998), has been refined and validated using later data. For the first time, the benthic IBI and physical habitat index (PHI) have been developed following the model of fish IBI development (using separate data sets for development and validation). These three indices are the basis for estimating the number of stream miles in varying degrees of degradation (good to very poor condition) and mapping the locations of sites by their condition.

The Survey has also developed a series of analytical techniques for characterizing biological communities, assessing their condition, and evaluating the relative contributions of different anthropogenic stresses. Previous MBSS reports have expanded the description of fish abnormalities (to address concerns about *Pfiesteria* outbreaks) and refined the narrative descriptions for the IBI categories (to improve their use for identifying impaired waters under the federal Clean Water Act). Investigation into the role of specific stresses in degrading Maryland non-tidal streams has improved in several ways. New analytical techniques were applied to determine whether the sources of acidification found in streams were acidic deposition or acid mine drainage. Additional parameters describing physical habitat condition were analyzed separately and as combined in the reference-based PHI. Information on nitrate-nitrogen concentrations in streams was evaluated and compared with data from the CORE/Trends program to address nutrient loading and downstream Chesapeake Bay concerns. Evaluations of the associations between stream parameters and land use in the upstream catchment draining to each stream site were added to provide a watershed context for addressing cumulative effects. The land uses in all of Maryland's 17 basins were characterized with the Multi-Resolution Land Characterization (MRLC) data set, information at a finer resolution than was available in 1995. In particular, low and high intensity developed areas were separated into separate land cover classes. Where possible, the Survey has looked at associations among multiple stresses and provided initial rankings of stresses based on their extent of influence (i.e., percentage occurrence in miles of stream).

Now that MBSS results from all three sample years (1995, 1996, and 1997) have been integrated, we have compared results among years and discussed the implications of interannual variability in precipitation and other factors. Statewide results also provide a better opportunity to describe the abundance and geographic distribution of rare species and other components of biodiversity. We have conducted additional biodiversity analyses to identify preliminary concentrations of species richness, rare species, and other areas supporting biodiversity. The statewide results in this report provide a framework for targeting areas for further assessment at a local scale, prioritizing areas for protection and mitigation of identified impacts, and monitoring restoration success or other trends in Maryland streams. To this end, a demonstration of species and indicator estimates at the county and small (138) watershed scales are included. The extent to which these analyses have answered the MBSS questions presented in Appendix A is discussed in the final two chapters of this report.

1.4 ROADMAP TO THIS REPORT

This report presents the results of the 1995-1997 statewide MBSS and includes 15 chapters and 8 appendices.

Chapter 2 provides a general description of the overall sampling design used by the Survey and describes the specific survey methods used. Chapter 2 also includes a brief description of the field and laboratory protocols and the statistical methods used in data analysis. Chapter 3 describes the environmental setting, placing the results in the context of their geologic, climatic, and human history. Chapter 4 characterizes Maryland's biological resources by taxa group; special attention is given to statewide fish estimates and discussions of important and declining species. Chapter 5 summarizes the results of assessing ecological condition using biological indicators (fish IBI, benthic IBI, and Hilsenhoff Biotic Index). Chapters 6, 7, 8, and 9 focus on issues affecting biological resources: acidification, physical habitat, nutrients, and watershed land use. Each of these chapters discusses the range of natural conditions and how they have been modified by human stresses in these categories. Chapter 10 is a brief discussion of how MBSS results vary among sample years and implications for interpreting the preceding results. Chapter 11 assesses the relative contributions of different stresses to the cumulative problems faced by Maryland streams. Chapter 12 analyzes the state of freshwater biodiversity, recognizing that rare species and other components are not captured by many of the MBSS indicators. The last two chapters summarize the conclusions of the statewide results and place them in the context of potential management and policy decisions (Chapter 13) as well as what questions remain to be answered (Chapter 14).

Appendix A contains a list of questions being addressed by the MBSS. Appendix B provides a table of the number of stream miles and sites sampled each year. Appendix C lists common and scientific names for all taxa collected in MBSS. Appendix D is a summary of the precipitation records for the 1995, 1996, and 1997 sample years. Appendix E provides summary tables with statewide estimates for habitat, water chemistry, and gamefish and non-gamefish populations. Appendix F is a table of all sample sites assessed as degraded with associated values for parameters that might indicate likely stresses. Appendix G is a table relating the 17 major drainage basins to the 138 small watersheds in the state and to Maryland's Tributary Strategies Basins. Appendix H contains tables listing the percentage of stream miles in each category of the fish and benthic IBIs as well as the Physical Habitat Index for the 24 Maryland counties and selected small watersheds.